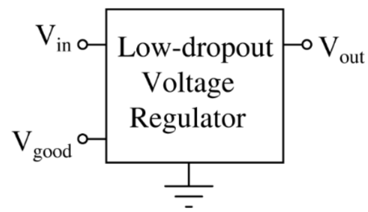
EE313 Laboratory #2

Low-Dropout Voltage Regulator

Design a simple method to measure β of a pnp transistor.

Design a low-dropout (LDO) (0.7V max) voltage regulator with an output current of 100mA. A green LED should turn on if the regulator output is good. Use a power pnp BJT (BD136) to regulate the voltage, an OPAMP (LM358) to provide the feedback, and a Zener diode as the voltage reference. The output voltage is determined using your Bilkent ID number: V_{out}= 7.5+mod(BilkentID,6)

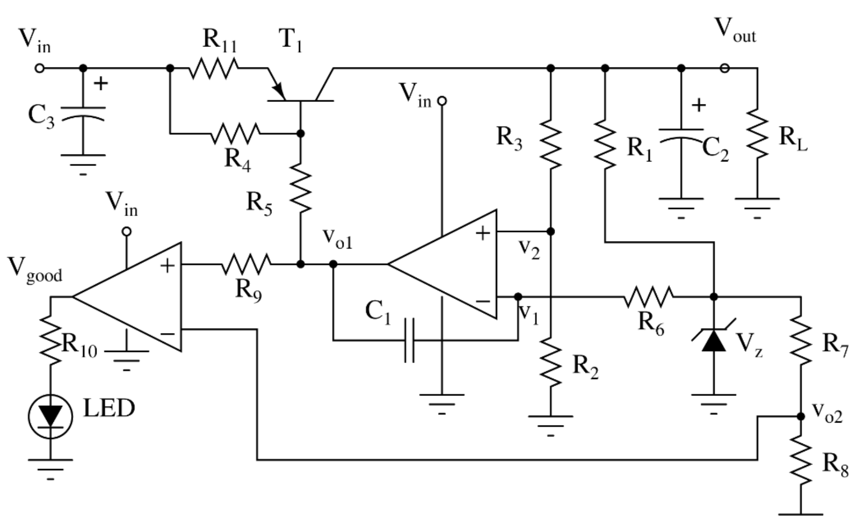


Specifications:

1. Line regulation: When V_{in} is varying between V_{out}+0.7 to V_{out}+6 at 100Hz, the output voltage, V_{out}, changes by no more than 20mV when the output current is 100mA (R_L=V_{out}/0.1).
2. Load regulation: When V_{in}=V_{out}+2, the output voltage, V_{out}, changes no more than 20mV when the output current changes between 0mA and 100mA at 100Hz. (In LTSpice, you can connect a sinusoidal current source at the output varying between 0 and 100mA.)
3. A green LED should turn on if the regulation is achieved. Otherwise, it should turn off, for example, because the input voltage is too low or the output current is too high.

Preliminary work

The following circuit can be used as an LDO:



- Choose a Zener voltage less than V_{out}. Available Zener diodes are 2.7V, 3.9V, 4.7V, 5.1V, 5.6V, 6.8V, 7.5V, 8.2V, 9.1V.
- Choose R_1 to have a Zener current of about 3mA. R_1=(V_{out}–V_Z)/0.003. Note that a Zener diode should dissipate no more than 100mW.

- The OPAMP can compare the reference voltage $v_1=V_Z$ with a scaled version of the output voltage, v_2, to provide the base current of the PNP transistor as feedback. Choose $V_{out}R_2/(R_2+R_3)=V_z$. Choose R_2+R_3, so the current through them is less than 1mA: $R_2+R_3 \geq V_{out}/0.001$. Determine the values of R_2 and R_3.
- Choose $R_6 \approx R_2 \| R_3$ to have equal resistors at the OPAMP inputs.
- Choose R_5 to provide the base current for T_1 when the load current is maximum and the input voltage at $V_{out}+0.7$. $R_5=\beta(V_{out}-1)/I_{Lmax}$. Here, β is the β_{min} of T_1 and $I_{Lmax}=0.1A$.
- Choose $R_4=0.8R_5$ so that when there is no load resistor, the base current of T_1 can be zero.
- Choose $V_XR_8/(R_7+R_8)=v_{o2}\approx 0.1V$. Choose R_7+R_8, so the current through them is less than 0.5mA. When v_{01} drops below 0.1V, the limit of the OPAMP is reached, and V_{good} should go low to turn off the LED. Otherwise, the LED should be ON.
- Choose $R_9 \approx R_7 \| R_8$ to have equal resistors at the OPAMP inputs.
- Choose R_{10} to have an LED current of 5mA: $R_{10}=(V_{in}-2)/0.005$.
- Choose $R_{11}=3.3\Omega$ to provide β stability.
- Increase the value of C_1 to kill the oscillation. If C_1 is absent, an oscillation in the output voltage may be present. The presence of C_1 reduces the feedback gain at high frequencies. If it is too large, the regulator cannot generate a constant output voltage with respect to fast changes at the input.
- Choose C_2 at least 10µF to provide stability.
- Set C_3=10µF as input filter capacitance.

Simulate your design using transient analysis of LTSpice to show the performance under three conditions given above: (Use the provided Spice files, LM358.txt for LM358 and BD136.txt for BD136 simulation. (Place LM358.txt and BD136.txt in the working directory. Insert .include LM358.txt and .include BD136.txt directives into the schematic. Define the Value property of the opamp2 symbol as LM358 and the value property of the pnp symbol as BD136.)

Use an electrolytic capacitor at the output to provide stability.

From the datasheet of BD136, find the junction to ambient thermal resistance ($R_{\theta JA}$), junction to case thermal resistance ($R_{\theta JC}$), and the maximum junction temperature (T_{Jmax}). Estimate the junction temperature (T_J) and case temperature (T_C) of BD136 when V_{in} is 3V greater than V_{out} and when a load resistor is connected at the output, drawing a current of 100mA. Assume that the ambient temperature is T_A=25°C:

$$T_J=T_A+R_{\theta JA}P_D \text{ and } T_C=T_J-R_{\theta JC}P_D$$

where P_D is the power dissipation on the transistor ($P_D=(V_{in}-V_{out})I_{out}=0.3W$).

To measure the line regulation, use a sinusoidal voltage source with a DC voltage of $V_{out}+3.35$ and a magnitude of 2.65. The peaks of this sinusoidal signal vary between $V_{out}+0.7$ and $V_{out}+6$. Initially, use a frequency of 50Hz. Then find the highest frequency of sinusoid, where the output ripple requirement of 20mV is satisfied. This frequency can be further increased by reducing the value of the capacitor used in the OPAMP feedback. On the other hand, if that capacitor is chosen too small, the regulator may oscillate.

Provide a schematic of your design, showing a component list. Use Diptrace to generate the schematic of your design.

Upload your LTSpice source file *.asc into Moodle and your pdf report containing the Diptrace schematic.

Experimental work

Measure β of the BD136 pnp transistor.

Build your design on a breadboard. Test the three conditions given above.

Provide a picture of your breadboard in the report.

Calculate the dissipated power on the load resistor. Note that common axial resistors found in the lab can dissipate only 250 mW. You must use a power resistor (8.2, 10, 15, 33, 47, 68, 100, and 150Ω available in the lab) or several low-power resistors in parallel if the power dissipation exceeds this value.

Grading criteria:

Preliminary work (10 pts)

β measurement method. 1pt.

Nice looking schematic with component list: 1pt.

Satisfaction of all three criteria in LTSpice: 6pts, 2 pts each

Temperature analysis of BD136: 2pts

Experimental work (10 pts)

β measurement. 1pt.

Experimental satisfaction of all three criteria: 9 pts, 3pts each